Teaching Machines and Programed Instruction

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The Relevance of Frame Sequence in Programed Instruction: An Addition to the Dialogue

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Careful sequencing of instructional stimuli has always been considered a highly important variable in programed instruction. As early as 1954, Skinner suggested the logical necessity of sequence: "The device [teaching machine] makes it possible to present carefully designed material in which one problem can depend upon the answer to the preceding and where, therefore, the most efficient progress to an eventually complex repertoire can be made [p. 90]." In 1958 Skinner wrote, "... technical terms, facts, laws, principles, and cases ... must then be arranged in a plausible developmental order [p. 974]." Basic to Skinner's approach is the notion that through empirical feedback from students to the programmer, there can be developed an ideal, or optimal, learning sequence (Lumsdaine, 1964, p. 383).

Present day programmers, while gradually becoming less restrictive in terms of many of Skinner's theoretical presuppositions (overt responses, individual pacing, constructed responses,

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etc.), still retain the notion of sequence. Note Susan Markle's 1967 definition: "We define an instructional program as a reproducible sequence of instructional events designed to produce a measurable and consistent effect on the behavior of each and every acceptable student [p. 104]."

Given the weighting assigned to sequence in programed instruction, experimenters over the past several years have been unable to resist the temptation to test the sequence hypothesis by comparing logically-ordered frame sequences with sequences whose "plausible developmental order" has been destroyed through randomization. At least eight of these so-called "scramble studies" have been reported since 1961 (Krathwohl, Payne, & Gordon, 1967; Levin & Baker, 1965; Miller, 1965; Niedermeyer, Brown, & Sulzen, in press; Roe, 1962; Roe, Case, & Roe, 1962; Stolurow, 1964; Wodtke, Brown, Sands, & Fredericks, 1967), and they constitute a rather perplexing state of affairs: a box score would indicate that only one of them, Roe (1962), has revealed a significant advantage for a logically ordered sequence on learner posttest performance. However, such a box score conclusion would be misleading since certain methodological weaknesses may be identified in some of these studies.

The purpose of this paper is to review this issue of frame sequence which compares the relative effectiveness of logically ordered frames versus randomized frame sequences in the learning of classroom subject matter using programed instruction. Before proceeding with an analysis of the research, perhaps it would be wise to examine one of the underlying theoretical concepts regarding frame sequence—the interrelation between the task types being taught and the degree to which frame sequence affects learning.

RELATIONSHIP BETWEEN TYPE OF LEARNING AND EFFECT OF SEQUENCE

Among the first to conclude that program content was probably a critical factor in determining whether or not sequence would affect learning were Levin and Baker (1965) when discussing the "no difference" results of their 1963 scramble study using a second grade geometry program. Since then, authors of sequence studies have generally selected programs from mathematics, where, supposedly, there are many instances in which certain things have to be learned before others—i.e., where sequence *should* be important relative to achievement. The model usually employed to describe such hierarchical learning is Gagné's (1965) concept of a knowledge structure where principles to be learned

depend upon previously acquired principles and concepts, which in turn depend upon previously learned discriminations among stimulus-response associations.

It is argued that a program developed according to such a rational analysis of the subject matter would exhibit a high degree of sequential dependence among its frames as learners work upward through the hierarchy of tasks. Randomizing this logical, hierarchical sequence in such a program should cause *Ss* to make significantly more program errors, and, it is implied, less learning will take place. On the other hand, if a program consists of a series of items in which the correct responses were independent of each other—such as a list of unrelated spelling words or historical facts—then the overall program error rate should remain constant no matter how the frames are sequenced since the items form rather a flat structure instead of a hierarchical or pyramid-shaped structure. Thus Krathwohl, Payne and Gordon (1967) state "... there may be a continuum of dependence on sequence [p. 126]."

Upon the basis of the above discussion, error rate differences are taken as an index of the degree to which logical sequencing is relevant in a particular learning program. Whenever a scramble study is reported in which logical and random program error rates do not differ very much (Krathwohl et al., 1967; Levin & Baker, 1965; Roe, Case, & Roe, 1962), it is argued that no learning differences should be expected since frame order did not seem to affect the learners' ability to respond correctly and thus there may not have been a necessity for any particular frame sequence in the program.

REVIEW OF EARLIER RANDOM SEQUENCE STUDIES

Disciples of linear programing were interested in 1962 when Roe, Case and Roe found no posttest differences after comparing normal order and scrambled sequences of a 71-frame program on elementary probability theory for college freshmen. The authors concluded that "... for short programs careful sequencing may not be important." Since such a conclusion was (and still is) quite upsetting to popular programing beliefs, critics quite naturally began to look for flaws in the study. Holland (1967) in his 1965 review, pointed out that "program error rate for the two [sequence] forms did not differ, suggesting that the items were not highly interdependent even in the 'sequenced' case, either because of the nature of the concepts taught or because of overcueing [p. 69]."

Shortly after this initial study, Roe revised the program adding 22 frames, and ran the experiment again comparing not only linear and random frame sequences but several types of branching sequences as well (Roe, 1962). This time the linear (logical) version did produce significantly better outcomes than the random version relative to error rate, time to complete the program, and posttest scores. Holland, in reviewing this second study, apparently accepted it as evidence enough, for he concluded that "... the need for sequenced material is supported, at least if the frames are interdependent and not severely overcued," and he further suggested, "What is needed now is not more studies of scrambled versus ordered sequences, but constructive and creative research which will indicate when, how much, and in what way items may be sequenced [p. 69]."

While Holland apparently considered the issue closed, an inspection of the data from the second Roe study (1962) reveals some problems. The "significant difference" Roe found for the posttest scores turns out to be only ten percentage points (59.4 percent versus 69.7 percent) which, on the 14-item test he used, is a difference of only one and one-half items. The significant learning-time difference was only 13 minutes on the two hour program (118 minutes versus 131 minutes). While these differences are statistically different, one wonders whether the magnitude of these differences is large enough to consider the issue closed. Another interesting outcome of this study was that a forward branching version of the logical sequence program administered via a programed text format (the others were administered via cards in file boxes) produced a mean six percentage points *lower* than the scrambled program. Nevertheless this is the only study the writer is aware of in which the outcomes have been consistent with programing theory.

Adding a new dimension to the previously discussed relationship between sequence and the type of material being taught, Stolurow in 1964 found an interesting interaction between IQ and sequence when comparing a mixed (random) sequence and a consecutive (logical) sequence designed to teach fractions to educationally handicapped high school students (mean mental age of 12 years). Only those with higher ability were successful using the mixed sequence, while all ability levels were successful with the consecutive ordering. Stolurow concluded that "... the best sequence [consecutive] did for the poorest ability group

what the highest ability groups could do for themselves regardless of sequence." Consequently, subsequent scramble studies to date have included the hypothesis that sequence effects may depend upon the learner's ability—high ability learners should be able to overcome the effects of poor sequencing better than low ability learners. (A logical corollary of this would be that the age of the learner may be relevant, yet it seems that most sequence studies have been conducted with college *S*s.)

RECENT RESEARCH ON THE ISSUE

Since Holland's 1965 review, at least four new studies on the issue have been reported, and all are in the "no difference" category.

Krathwohl, Payne and Gordon (1967) examined the effects of scrambling upon the learning of three college statistics programs which "varied in the *judged* logical interrelatedness of the material in each program from low to fairly high [p. 126, emphasis mine]." They found no treatment effects and no interactions with ability. However, several problems may have hampered the validity of this study. Error rates for both logical and random sequence conditions ran between 4 percent and 6 percent, and controls scored almost as high as treatment *S*s. Also the instructional conditions were uncontrolled in that subjects were requested to complete the programs at home.

Miller (1965) reported a study in which a 98-frame program on topics in ratio and proportion was presented in both logical and random sequences to middle-track seventh-graders. While error rates differed substantially (5 percent on logical versus 13 percent on random), instructional time differed very little (50 minutes on logical versus 56 minutes on random), and criterion test scores differed not at all (both means were about 38 on a 50-item test). Also the pretest mean was 29, indicating only 9 items on the 50-item test. It would seem that the *S*s knew quite a bit of the material prior to instruction, thus making it easier for them to overcome the effects of random sequencing.

A Key Study

Wodtke, Brown, Sands and Fredericks (1967) recently reported two well controlled experiments where computer terminals were used and a comparison of random and logical sequences of instruction in two content areas were made.

In the first experiment, a 74-frame program on number bases was administered to 80 education majors at Pennsylvania State University. This program was thought to contain a conceptual hierarchy where sequence would be important. As was ex-

pected, a significant difference in program error rates did appear, favoring the logical order, and the experimenters took this to ". . . support their contention that the ordered version of the modern mathematics program . . . did contain an ordered conceptual sequence . . . [i.e.] the conceptual hierarchy model suggested by Gagné which implies that the mastery of subordinate tasks in the hierarchy is essential to mastery of tasks at higher levels in the hierarchy [p. 64]." Contrary to expectations, however, there were no achievement differences or aptitude-sequences interactions with respect to posttest performance.

The second experiment utilized a program teaching discrete facts relative to the anatomy of the ear, and no effect for sequence was hypothesized. The material apparently was nonhierarchical or flat in structure, and there was no error-rate difference, as well as no posttest difference, between sequence groups in this second experiment.

This study contained several features that were an improvement over previous scramble studies. The number base program was an effective instrument for producing criterion behaviors (mean of 18 on a 22-item posttest), and it dealt with knowledge for which the *S*s had little or no previous background (90 percent of the *S*s scored zero on pretest). The learning situation was extremely well controlled through the use of a computer teletype terminal. The achievement test was reliable ($r = .93$), and examination of it and the program indicated content validity. How then does one account for the fact that no differences in achievement were found? The authors offered the following explanation:

> . . . adult *S*s are able to relate the relevant information as it is made available by the [scrambled] program to the previously poorly understood concepts which were presented out of sequence . . . this interpretation leans heavily on the cognitive processes of the *S*s which allow them to integrate and organize information regardless of the sequence of presentation [p. 31].

The authors contended that their data raised "some embarrassing questions" for programed instruction theorists:

> . . . we would venture the tentative conclusion on the basis of accumulated evidence to data [here they are referring to previously mentioned studies], that instructional sequencing may be an overrated variable . . . manipulations of instructional stimulus variables may account for only a very small portion of the variance accounted for

by the learning strategies and information processing strategies employed by the students. [p. 67]

ANOTHER INVESTIGATION

After considering some of the conceptual and methodological problems in several of the above studies, and after admitting an intuitive unwillingness to believe the trend of "no differences," the author, along with two colleagues, undertook still another scramble study. This experiment (Niedermeyer, Brown, & Sulzen, in press) was recently completed and is reported briefly here.

The Program

From the outset, we attempted to secure a learning program on which there existed empirical data as to the high degree of interdependence among the concepts and principles being taught, i.e., where sequence had been proven to be highly relevant. Consequently a modified version of the *Number Series* program from Gagné and Brown's 1961 study on discovery learning, "Some Factors in the Programing of Conceptual Learning," was employed for this experiment. The program consisted of 70 introductory frames (there were 89 originally, but some of the repetitious practice frames were removed due to time constraints) followed by 40 guided-discovery frames.

These latter frames required the learner to "actively produce . . . concepts . . . which he had just previously learned in the introductory program" in order to attain the problem-solving skill of "finding a formula for the sum of *n* terms in a number series" (Gagné & Brown, 1961, p. 319). For example, in the discovery part of the program the learner would be given a number series, such as 1 2 4 8 16 32 64 etc., and then would be guided through a series of ten frames to produce the formula for the first *n* terms in in this series, which happens to be

$$\overset{n}{\Sigma} = T_{n+1} - 1.$$

Presumably it would seem that in order to perform this task the learner would at least have to understand the symbolized concepts (Σ, n, T), principles interrelating these concepts, and subscript notation—all of which are taught in the 70 introductory frames.

This particular learning program was selected because it was thought to be based on the knowledge hierarchy empirically validated for this same terminal task (finding formulas) by Gagné (1962). However, it later became apparent that the *Number Series* program must have been developed prior to Gagné's derivation of this knowledge hierarchy since little correspondence

could be found between the frames of the learning program and the tasks identified in the hierarchy. This, unfortunately, prevented us from randomizing the presentation order of task units within the program, and instead we had to scramble all of the frames. We also decided that, besides destroying the logical sequence in Gagné's program by randomizing the frame order, the program would also be administered in *reverse* frame order—the rationale being, "If this fails to impair learner achievement, then we have some real thinking to do about frame sequence."

Results Sixteen ninth-grade algebra students in each of the three sequence groups plus a control served as the subjects. Inprogram measures (see Table 1) indicated that there were no differences between sequence groups in the amount of time taken to complete the frames. Program error rates, however, did differ significantly ($p < .05$) in favor of the logical sequence group, thus indicating a substantial sequence effect in the program. The rather high magnitude of the error rates, even for the logical *Ss*, suggests that the program was quite difficult for this particular sample of ninth graders. Much lower error rates were obtained for this same program in Gagné and Brown's study (1961) and in a replication of their study by Meconi (1967), but this could perhaps be explained by an aptitude difference in the samples. The IQ range for the present study was 93 to 137 (mean of 112) whereas in the Gagné and Brown study the range was 100 to 154, and in the replication study (Meconi, 1967) the mean was 128.

TABLE 1
Time to Complete Program and Errors on Program for Each Sequence Condition ($N = 16$ for Each Group)

	Measure				
Sequence	*Time (Minutes)*		*Program Errors*		
Condition	*M*	*SD*	*M*	*SD*	*Error Rate*
Logical	78.5	15.3	38.2	16.6	35%
Scrambled	80.9	13.6	54.8	17.0	50%
Reverse	81.5	6.5	52.1	13.8	47%

Of course it could also be argued that the required responses in many of the frames were undetermined or uncued. Holland (1967) discusses this problem, and if it were valid for the *Number Series* program, then the effectiveness of the program to teach the required behaviors could be questioned. However, inspection of the frames indicates that undercueing was not

the problem, and one boy in the logical group made only nine program errors during the experiment.

Results of postprogram measures for each sequence condition and the noninstructed controls are given in Table 2. The *Test of Introductory Concepts* consisted of ten tasks taken directly from the program, but applied to a new number series.

TABLE 2
Performance Measures on Test of Introductory Concepts and Transfer Test of Problem Solving Skill for Each Sequence Condition and Control Group

	Measure			
	10-Item Test of Introductory Concepts		*10-Pont Transfer Test of Problem Solving Skill*	
Sequence Condition	*M*	*SD*	*M*	*SD*
Logical ($N = 15$)	5.5[a]	3.1	3.3[a]	3.0
Scrambled ($N = 16$)	4.1[a]	2.9	1.8	3.0
Reverse ($N = 16$)	3.4	3.5	2.6[a]	2.1
Control ($N = 16$)	0.8	1.0	0.3	0.7

[a] Significantly different from Controls, $p < .05$

$$\text{example: If } T_n = 9, \text{ then } \overset{n}{\Sigma} = \text{——}?$$

The Transfer Test of Problem Solving consisted of five new number series for which the *S* was expected to state a general equation that would give the sum of the series at any term, *n*. Three of these number series had been used as test items by Gagné and Brown, and the other two were developed by the experimenters. Responses to each of the five series were scored on a two-point basis for a total of ten points.

For both tests, analysis of variance indicated significant differences among the means ($p < .01$). A posteriori comparisons, however, using the Scheffé method (Ferguson, 1966, p. 296) to hold the probability of a Type I error constant, reveal that *only* the logical sequence group performed significantly better than the control group on *both* tests. The scrambled sequence group performed significantly better than the controls on the *Test of Introductory Concepts* but not on the *Transfer Test.* The reverse sequence group performed just the opposite. None of the three sequence groups differed significantly from each other on either test. These results, while in an encouraging direc-

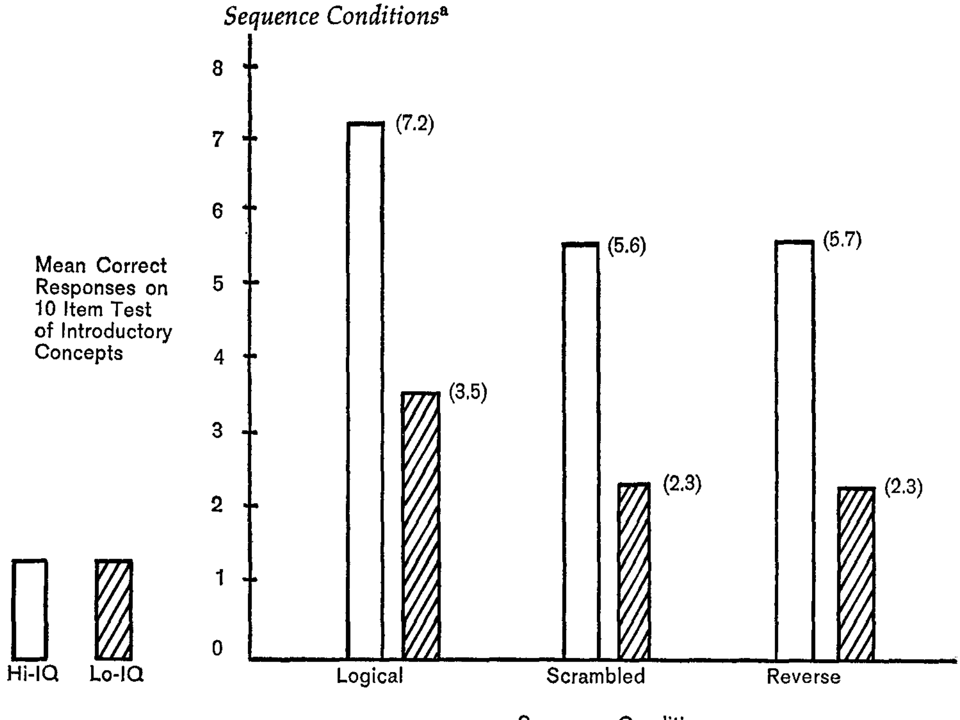
tion, certainly are not sufficient for closure on the issue of frame sequence.

The possibility of IQ and sequence interaction effects on the *Test of Introductory Concepts* was examined by means of a factorial analysis of variance and no significant effects for either sequence or sequence X IQ interaction were found.

Figure 1 presents means of each sequence group on the *Introductory Test* after the Ss had been split at the median IQ of 114. While it is obvious that little interaction effect exists, it is interesting to note that for the upper half of the Ss relative to IQ the program appears fairly effective. Again it was concluded that the problem with the program was that it was too difficult for this particular sample of Ss and not that the program was simply ineffective.

An attitude measure administered by the classroom teacher the day following the study revealed an interesting difference

FIGURE 1 *Mean Number of Correct Responses on Test of Introductory Concepts by High and Low IQ Ss Under Logical, Scrambled, and Reverse Sequence Conditions*[a]



[a] N's Equaled: Hi-IQ/Logical = 7, Hi-IQ/Scrambled = 9, Hi-IQ/Reverse = 6, Lo-IQ/Logical = 6, Lo-IQ/Scrambled = 7, Lo-IQ/Reverse = 9

among the groups. *Ss* in the logical sequence group tended to consider the program "interesting," whereas *Ss* in the scrambled and reverse treatment groups tended to feel "neutral" about the program ($\chi^2 = 6.6, p < .05$). No differences were found relative to how difficult the *Ss* felt the materials and the tests were. That the logical *Ss* felt the program was more interesting than *Ss* in the other two groups would be expected because their error rate on the program was substantially less. The program was not as punishing for *Ss* under the logical sequence condition. It is also possible the logical group *Ss* professed higher affect toward the program because they were able to follow the simple-to-complex development from concepts and principles to problem-solving skills, whereas *Ss* in the other two groups were never able to figure out what the program "was driving at" even though they learned to perform some of the tasks taught in the program.

Conclusions

It was concluded, "Though sequence effects would be expected to appear in a fairly long instructional program, the present study, as well as previous studies, lead the authors to believe that for short (less than two hours) programs, sequence may not be as crucial to cognitive outcomes as has previously been thought." We also noted, however, that the significant difference in learner affect "may be enough to justify careful attention to frame sequence in short instructional programs" (Niedermeyer et al., in press).

WHY NO DIFFERENCES? A DISCUSSION:

Anderson, in his 1967 review, argued that "no difference" results from scramble studies could be explained in terms of a spaced practice effect: "It seems possible that the disruptive effect of presenting frames out of order was counterbalanced by the facilitative effects of larger intervals between similar frames [p. 157]." This writer would agree with Anderson when the task to be learned is a rather simple, one-step principle or an instance of a particular concept. It can be noted from the data in Table 2 that the random sequence group performed higher than the reverse order group on the *Test of Introductory Concepts* where the learner had to respond correctly to instances of recognizing and using concepts. (Example: If the term-value from the above number series is 8, then what is the corresponding term number?) Any of these tasks could be presented in a single frame and thus random group *Ss* may have benefited from the spaced practice effect advocated by Anderson.

On the other hand, it will also be noted that the random sequence group was not even statistically superior to control *Ss* on the *Problem Solving Test* where they had to derive a formula by following a *series* of guided-discovery frames during the latter part of the program. Randomization apparently destroyed any guiding effects present in these series of frames. *Reverse* order *Ss*, however, did perform statistically better than controls on the *Problem Solving Test.* The guided discovery sequence of frames, while presented backwards to this group, apparently was not completely destroyed and *Ss* were able to garner some problem-solving competency. One boy in the reverse order group remarked during instruction, "Whenever I begin to understand what they are doing, they switch to something new." What we are saying here is that sequence seems to have been more important in the latter, problem-solving part of the program than in the introductory part where each frame represented a simple, discrete task.

In wondering how reverse order *Ss* could even attempt the problem solving (finding formulas) frames without having gone through the introductory frames which taught the supposedly prerequisite concepts, it could be argued that these *Ss* figured out for themselves the prerequisite behaviors by using knowledge of correct answers provided on the back of each frame. Many reverse order *Ss* were observed spending considerable time looking back at a frame once they had exposed the correct answer. In such a manner they may have been able to comprehend the meaning of the symbols used for writing the formulas. Some Ss, on the other hand, did not use knowledge of correct answers to look back at a frame and fill in the gaps. Instead, they would merely register a facial expression that signified displeasure (they were wrong or unable to answer 50 percent of the time) and move immediately to the next frame.

The experimenters found the above phenomenon quite interesting and a study could be planned in which, on missed frames, latencies after receiving knowledge of correct answers before going on to the succeeding frame are measured. It might be hypothesized that those *Ss* showing the greatest persistence would probably learn the most. If this hypothesis held up, it could be argued that problem-solving programs, where prerequisite skills must be searched out by the learner himself, might be a useful application of programed instruction relative to pro-

moting learning-how-to-learn behaviors. Logically-ordered, small-step, minimal-error-rate programs that are held in such high esteem at present may effectively promote desired cognitive outcomes, but, through overuse of spoonfeeding through sequence, may not promote desirable study skills and searching behaviors. This, fortunately, is an empirical question and one that may be worthy of investigation in the future. Two girls in the study (Niedermeyer et al., in press) worked through the program in *reverse order* and made perfect scores on both posttests. One of these had an error rate of only 15 percent. How did they do it? Control group scores indicate little chance of prior experience with the program content. If we could identify the information-processing strategies they must have employed, then there exists the possibility that we could actually teach these behaviors to others.

While many of the studies on the issue of frame sequence possess certain methodological deficiencies, some of them—especially the Wodtke et al. (1967) study—seem valid enough to agree with Evans (1965) that "... it is possible that with very short programs, scrambling the order of the items may make little difference [p. 385]." While Evans also states, "... it seems highly unlikely that any successful, well-revised program of more than 100 frames in length, in highly structured topics such as mathematics or logic, could be successfully scrambled in its entirety and still do the job it was designed to do," we would once again point out that the evidence accumulated to date implies that programs considerably longer than Evans suggests may be relatively unaffected by frame sequence. We cannot concur with programing theorists who seem to infer that careful regard for optimal sequencing is crucial in all cases. Indeed it has already been argued that careful frame sequencing which leads learners through subject matter with a minimum of frame errors may be detrimental to certain desirable outcomes related to learning how to learn.

AN ALTERNATIVE FOCUS TO FRAME SEQUENCE

Since the writer seems to be discounting (though certainly not dismissing) the role of frame sequence in short programs, one might wonder just what it is he does consider crucial to learning outcomes. In attempting to answer this question, let me first attempt to clarify what seems to be a confusion between Gagné's hierarchical learning structures, on one hand, and program frame sequence on the other. Several of Gagné's experiments (Gagné,

1962; Gagné, Mayor, Garstens & Paradise, 1962; Gagné & Paradise, 1961; Gagné & staff, 1965), each containing a rather complex task hierarchy, have shown, indeed, that once a learner fails when tested on a particular task, he also fails all higher level tasks in the structure. It is easy to see how people might interpret this as synonymous with the sequence in which instructional stimuli *must* be presented to learners. Yet this simply is not true. It has been shown in several of the previously reviewed studies that instruction relative to prerequisite tasks forming a learning structure can be presented in a random or even a reverse order without substantially affecting the amount of end-of-program learning that takes place.

What Gagné is saying, quite accurately, is that some things must be learned before others—the concepts that comprise a principle must be acquired before the learner can show his understanding of the principle, etc.—yet this sequence of learning is quite different from sequence of instructional frames or stimuli. Although *S*s may miss frames requiring the understanding of a principle when they do not have mastery of prerequisite principles and concepts (thus causing program error rate to increase), the chances are that they will later (on posttest) be able to perform adequately on this task either because of using knowledge of correct answers supplied in the program or because of mental reorganization when they eventually come to instruction on the prerequisite skills.

This distinction between learning sequence and instructional sequence is essentially one of means and ends. The sequence of frames in a program is a *means* question; it is concerned with how tasks are learned. The necessity for learning sequence as defined by Gagné, however, is an *ends* question; it asks, What are the subordinate tasks that must be acquired by the learner in order for him to perform this particular terminal task? And, as Gagné has pointed out many times (Gagné & Brown, 1961), "*What* is learned is more important than *how* it is learned [p. 320]." It is far more important to be concerned with what should be learned, with the identification of all relevant subordinate behaviors (task analysis) for a particular learning objective, than it is to be overly concerned with how (in what order) instruction relevant to these subtasks is presented. Note that in the typical scramble study all *S*s respond, in different sequences, to the same set of frames. The *what* is held constant and the

how is manipulated. As has been seen, the usual result of this is very little differences in posttest performance. The writer would contend that a programmer manipulating frames in search of an optimal sequence is wasting his time if those frames do not contain instruction pertaining to all subordinate tasks that the learner must be able to perform in order to acquire the final task.

Rather than relying on the manipulation of frame sequences in order to improve a program, many are suggesting that much more work be done prior to even writing the frames. David Markle's description of the development of a first-aid course for Bell Telephone (1967) provides an excellent example of this. After determining the behaviors desired for the course, test items were written for these objectives and tried out on many learners in order to (a) delete skills that could already be considered common knowledge to the target population and (b) to identify those items which were difficult or ambiguous so as to modify the corresponding tasks to be taught. Commenting on this preinstruction tryout technique, Markle states, "Ambiguities and inefficiencies were revealed in a surprising number of the items. Identification of such problems has critical implications for the later stages of instructional materials design, because an undetected inefficient question will lead to the design of concommitantly inefficient instruction [p. 13]." Thus an "empirical specification of objectives" was obtained before any instructional materials were developed and tried out.

In summary it would seem that worthwhile results would come from more emphasis on determining and verifying what has to be taught in a program rather than focusing primarily on how it is taught. Gagné's concept of task analysis, along with his hierarchical taxonomy of learning types (1965) to guide this analysis, may be useful. Once the programmer has determined precisely what a given group of learners has to be able to do in order to perform the terminal tasks, and after he has written instructional frames for all of these tasks, it may or may not be that relevant how he sequences the instruction. Please note that the writer is not advising programmers to ignore frame sequence and simply order them at random! Rather, it is being questioned whether or not traditional emphasis on frame sequence in programed instruction is really as critical to learning as has been theorized; and an alternative focus has been suggested.

As usual Robert Mager gets the last word (Mager & Beach, 1967): "Where it *is* necessary to teach one thing before another, do so. But be careful! There isn't nearly as much reason for this kind of sequencing as instructors like to believe [p. 60]."

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